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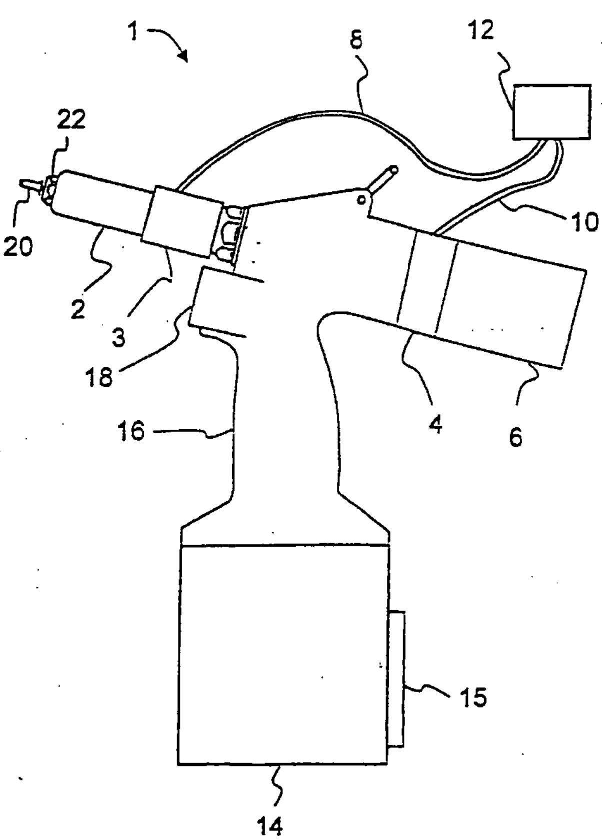
(54) Title: PLACING TOOL WITH MEANS FOR CONTROLLING PLACING PROCESSES

(54) Bezeichnung: SETZWERKZEUG MIT MITTELN ZUR KONTROLLE VON SETZVORGÄNGEN



(57) Abstract: Disclosed is a rivet placing tool (1) comprising a head piece (2) for receiving a rivet (20), a device for gripping a riveting bolt, and a pulling device connected to the device for gripping a riveting bolt in order to improve control of riveted joints during rivet placing. Said rivet placing tool (1) also comprises a device for measuring the tensile stress of the pulling device. The inventive rivet placing tool (1) makes it possible to detect the cause of a fault by comparing measured variables with stored variables.

(57) Zusammenfassung: Um eine verbesserte Kontrolle von Nietverbindungen beim Nietsetzen bereitzustellen ist ein Nietsetzwerkzeug (1) mit einem kopfstück (2) zur Aufnahme einer Niete (20), einer Einrichtung zum Greifen eines Nietstiftes und eine mit der Einrichtung zum Greifen eines Nietstiftes verbundene Zugvorrichtung vorgesehen, welche zusätzlich eine Einrichtung zur Messung der Zugspannung der Zugvorrichtung aufweist. Mit dem erfindungsgemässen Setzgerät (1) kann durch einen Vergleich von gemessenen Werten mit abgespeicherten Werten ein Fehlerursache festgestellt werden.

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(54) Title: **PLACING TOOL WITH MEANS FOR CONTROLLING PLACING PROCESSES**

(57) **Abstract:** In order to provide for improved monitoring of rivet joints during rivet setting, a rivet setting tool (1) is provided that has a head piece (2) for accommodating a rivet (20), a mechanism for gripping a rivet stem, and a pulling device connected to the mechanism for gripping a rivet stem; the tool also has a device for measuring the tensile stress of the pulling device. The setting device (1) in accordance with the invention makes it possible to establish the cause of a fault by comparing measured values with stored values.

Placing Tool with Means for Controlling Placing Processes

Description

The invention concerns a setting tool with means for monitoring setting operations.

Setting tools with means for monitoring the setting process are known. Thus, DE 4,401,134 describes a method in which a force component is measured over the stroke distance and compared with a nominal curve. This is intended to monitor whether the setting operation has been accomplished properly. EP 0,738,551 (US 5,666,710) discloses a device for verifying the setting of blind rivets. Here, the pulling force and the position of the pulling shaft are measured. The converted energy is determined by means of an integrator and compared to a nominal value.

The disadvantage of these known means for monitoring the setting operation is that, while it is possible to determine with a certain probability whether the setting operation lies within a given tolerance limit, it is not possible to determine the cause of a fault. A wide variety of faults can occur in a setting operation, for example operator error such as skewed placement of the setting device, holes that are too large, incorrect rivets, or defects in the rivet itself. In blind riveting, there also is always the danger that the rivet grips only the piece to be fastened without gripping the mating piece.

The object of the invention is to provide a setting tool that monitors the setting operation while also detecting the cause of a fault as it occurs. A further object of the

invention is to make possible comprehensive monitoring of various parameters of a setting operation.

This object is attained in a surprisingly simple way with a setting tool according to the features of claim 1. In accordance therewith, a setting tool is equipped with a head piece, especially for accommodating the rivet, a gripping and/or pulling mechanism and, connected to the gripping and/or pulling mechanism, a pulling device which has means for measuring the parameter values arising during the setting operation, a mechanism for comparing the measured values with stored values, and a mechanism for determining a cause, in particular a cause of fault, for the deviation of measured values from stored values.

The setting tool, which can be of a wide variety of types, thus for example rivet setting tools, blind rivet nut setting tools, or lockbolt setting tools, has sensors. By means of the sensors, various parameters can be measured such as position of the pulling device, time since the start of the setting operation, and the tensile stress exerted. These measured values are compared to stored values. Not only do the stored values include a nominal curve, deviations from which are assumed to constitute a faulty setting operation, they also include values for certain faults. These values may be present merely as individual values, or also as a nominal curve with various parameters that describe a specific fault. The quantity of stored fault causes includes at least one cause of fault, which may be enough for some applications. Preferably, however, a multitude of different causes of faults are stored. In addition to faults, it is also possible to determine the cause of deviations which, while they still lie within the tolerance range, are not ideal. In this context, the setting device is preprogrammed for

a very specific setting process that is defined, for example, by the rivet used and the type and thickness of the material used. Programming for multiple different setting processes is also possible. As a result of the invention, it is possible to correct the cause of the fault as quickly as possible. Since operator errors are also detected with the invention, the setting device is also eminently suitable for untrained operators. The quality of each setting operation can be monitored by means of the invention. This is of great benefit in the aerospace field, for example. While some rivets used in this field are subjected to X-ray inspection, the inspection cannot ensure that the riveting operation has proceeded faultlessly. With the invention, it would even be possible in theory to omit the costly X-ray inspection and still be able to guarantee the durability of the rivet joint.

Preferred embodiments and refinements of the invention may be found in the respective subordinate claims.

In a preferred embodiment of the invention, the measured parameter values show the tensile stress exerted by the pulling device and/or the position of the pulling device and/or the time since the start of the setting operation in question and/or the angle to the surface to which the setting device is being applied. Comprehensive fault diagnosis is possible using these values. This can also be accomplished by converting the values into curves or multidimensional performance graphs.

In a preferred embodiment of the invention, monitoring is performed to determine whether the device is applied at right angles. Often the operators do not apply the device precisely at right angles. This reduces the strength of the joint.

It is useful to also monitor whether an incorrect rivet is being used. There are rivets that look the same visually but are made of different materials, and thus have completely different strengths. This monitoring can be accomplished, for example, using the curve of the tensile stress exerted by the pulling device.

Another embodiment monitors whether the rivet is defective. For example, material defects in the rivet result in a different force curve.

Another embodiment monitors whether the hole provided for the rivet is too large or too small. With the setting device according to the invention, it is also easy to determine whether a rivet is present in the device, for example by measuring the tensile stress exerted. It is especially useful to monitor whether the rivet grips both of the parts to be joined. Particularly in blind riveting, it is frequently the case that the rivet does not grip both parts to be joined. Nor can the operator monitor this himself, since he can see only the part to be fastened and not the other side. If the rivet grips only the part that is to be set, the tensile stress exerted by the pulling device will rise later, or at a longer stroke. The fault can be easily identified in this way.

In another embodiment of the invention, monitoring is performed to determine whether the setting tool is defective or damaged. Thus, for example, the oil level in the pulling device can be too low. Consequently, the pulling device moves stiffly and no longer operates with the specified pulling force. Ideally, several of these causes of faults are programmed into one device. Programming of the device can be accomplished by performing a test series in which faults are caused intentionally. The deviations in the measured values arising for the respective faults can then be stored in the device for comparison with later measured values. In addition to performing strict monitoring of

faults, it is also possible to compare the deviation of a setting operation that still remains in the applicable tolerance range to an ideal value.

A preferred embodiment of the invention has a mechanism for measuring the position of the pulling device and/or for measuring the tensile stress exerted by the pulling device. The position of the pulling device and the tensile stress exerted are two of the most important parameters, which can be used to determine a large number of causes of faults.

As provided in a useful embodiment of the invention, the tensile stress exerted by the pulling device is measured with a strain gauge. Such a strain gauge for measuring stresses is reliable and cheap. The tensile stress is essentially proportional to the pulling force exerted by the pulling device.

In an alternative embodiment, the invention has a piezoelectric sensor for measuring the tensile stress exerted by the pulling device. This piezoelectric sensor requires no power supply.

A useful embodiment of the invention has a capacitive sensor for measuring the position of the pulling device. Such a capacitive sensor is far more precise than the optical sensors frequently used.

In a further development of the invention, the angle to the surface on which the setting device is applied, is measured by means of at least three sensors arranged on the head of the device. These sensors touch the surface that the device is applied to when it is applied at right angles. In this way, a common error of operators can be diagnosed.

In a further development of the invention, the setting tool has means for data storage and/or further processing. Thus, the measured values can be statistically analyzed. The user can, for example, monitor precisely how many setting operations have been completed, how many of them were faulty, and what the causes of faults were. It is, moreover, possible for the values of the correctly completed setting operations to be analyzed, for instance in that deviations of the values from the ideal values are stored and analyzed. Comprehensive quality control is possible in this way.

The manufacturer of the tool can monitor the function of his devices. It is also conceivable that the tool itself will not be purchased, but instead the manufacturer will make the tool available to the customer, who then will pay based on the number of setting operations performed, for example. It is also extremely advantageous for the provision of a manufacturer's guarantee if the manufacturer can use the tool itself to detect potential faults and possibly prevent them.

In a useful embodiment of the invention, the means for data storage and further processing are resettable, especially during servicing of the device. Thus, for example, after being reset the device can be issued to the customer like a new unit.

A useful embodiment of the invention has a chip for comparison of measured and stored values and/or for data storage and further processing. Such a chip can be tailored precisely to the requirements of the device. Moreover, this permits the smallest possible size. In contrast to EPROMS, which can also be used, the chip offers the additional advantage that it is significantly harder to manipulate.

In a useful embodiment of the invention, the comparison of measured and stored values and/or the storage and further processing of data take place in the device. Using

modern microelectronics, it is possible to integrate the entire analysis unit in a handy device.

It is useful for there to be provided in the device an independent energy source, in particular a rechargeable battery, for the means for comparison of measured and stored values and/or data storage and further processing. This ensures that stored measurement values are not lost even in the event of a prolonged power failure.

It is useful for the setting device to have a counter that counts rivet setting cycles and/or faults and/or causes of faults. Thus, statistical fault analysis is possible with the device itself.

In a further development of the invention, the setting device has an arrangement for recording the date and/or time. Thus, the setting operations and possible faults can be associated with a specific point in time. It is thus possible to establish after the fact precisely when, and thereby often where, a particular fault occurred.

A further development of the invention has an arrangement for transmitting measured values to an external unit. A computer system is an example of a possible external unit that can be used for accomplishing additional storage and analysis of the measured values supplied by the setting device. The individual setting devices could be allocated to the system via their device numbers, for example.

It is useful for the arrangement for transmitting measured values to include an arrangement for transmitting infrared, ultrasonic or radio signals, in particular "Bluetooth." There is thus a cheap and reliable standard component for wireless transmission using Bluetooth, for example.

Alternatively, the external unit can comprise a mobile radio terminal device. In this way, wireless transmission is possible even over long distances, such as to the manufacturer of the setting device.

In a useful embodiment of the invention, the setting tool has an arrangement for turning off the rivet setting device and/or displaying the cause of the fault in response to a signal generated in the event of a faulty rivet setting operation. In this way, it is also possible to refrain entirely from carrying out a setting operation when a fault is indicated from the very start. If the device is not applied at right angles, it does not trigger at all. The same applies when no rivet is present in the device. Termination of the setting process with display of the fault cause is even possible if only the component to be fastened is gripped during setting of a blind rivet.

It is also conceivable for the signal to be generated by an external unit, for example a connected computer.

In a further development of the invention, the setting tool can also include a device for connecting to a local network, which facilitates fast transmission and further processing of the data. In the context of sequential assembly steps, for example on an assembly line, fast reporting of a fault is especially advantageous so that the entire assembly process does not come to a halt for long periods.

The pulling device of the setting tool can be operated electrically, in particular with a rechargeable battery, electrohydraulically, hydraulically, or hydropneumatically. It is also possible to provide an entirely cordless device with rechargeable battery and wireless data transmission.

In a further development of the invention of a non-cordless device, the setting device has a line for supplying compressed air or electricity, and at least one additional line for transmitting the measured values, and the additional line forms, together with the first line, one cable with one connector. Thus, there is no need to connect two lines for energy supply and data exchange. It is conceivable to provide a combination plug with, for example, a compressed-air pipe and adjacent lines for data transmission.

In a further development of the invention, the setting tool performs a test cycle after switch-on. In this way, faults with regard to the device can be excluded prior to use. In order to check, for example, whether the tool is mechanically in order, the pulling device can be automatically advanced and retracted after switch-on. In the event that the pulling device moves stiffly, the tool indicates the fault.

The object of the invention is further attained by a method for monitoring setting operations, in particular rivet setting operations, in accordance with the features of claim 28. In accordance therewith, a part to be set is inserted in a setting device, preferably a setting device according to the preceding claims, and then a pulling force is exerted by a pulling device on the part to be set. The values arising during the setting operation are measured. The values thus measured are compared with stored values. Finally, based on this comparison, the cause for a deviation of measured values from stored values is determined from a number of stored causes.

Moreover, the invention concerns, in accordance with the features of claim 38, a head piece for a setting tool with means for measuring the parameter values occurring during the setting operation, having a device for comparing the measured values with stored values, and having a device for determining the cause of the deviation of

measured values from stored values from a number of stored causes. This head piece attains the object of the invention as does the setting device. A head piece makes it possible to equip an existing setting device with the functions according to the invention.

The invention further concerns a setting tool with a piezo sensor and a method for setting parts to be set, preferably rivets, in particular a device and a process for setting rivets with tensile stress measurement, and a head piece for a setting tool.

Rivet joints are used in industrial production in a variety of ways to join components. With regard to safety, high demands are placed on the stability and long-term durability of assemblies in this context, especially in the automotive and aviation industries. The stability of a rivet joint is critically dependent on the course of the riveting operation. For example, if the stem of a blind rivet breaks off too soon, the strength and durability of the rivet joint are endangered or at least are less than optimal. Similar also applies if, for example, the blind rivets are not inserted straight into the opening in the metal sheets, or if the opening for the rivet is not optimally matched. The latter arises, for example, as a result of out-of-round openings or openings with the incorrect diameter.

Known rivet setting tools set rivets with preset parameters, such as the pulling force to be used, for example. Under optimal conditions, a rivet setting operation using such a device may also produce an optimal result, but deviations from the nominal parameters which affect the strength of the joint are not detected in this process. This is especially important because a defective rivet joint can have the same appearance as a properly set blind rivet or rivet nut under external examination. Such faulty joints have

adverse effects on the quality of the assemblies produced with them and, in safety-critical fields such as aircraft manufacture, can even have fatal consequences.

From EP 0,454,890 is known a rivet setting device that is equipped with a force measurement arrangement that ensures that the rivet setting device operates with a predetermined pulling force. The force measurement arrangement has a strain gauge. Such strain gauges have the disadvantage that a voltage supply is required for them, and that the strain gauge does not by itself convert the pulling force into a voltage signal.

The present invention consequently has the object of providing an improved monitoring of rivet joints during rivet setting. This object is attained in an astoundingly simple manner by a setting tool in accordance with claim 60 and a method for setting in accordance with claim 77 and a head piece for a setting tool in accordance with claim 82. Advantageous further developments are given in the respective subordinate claims.

Provided accordingly is a rivet processing tool, more particularly rivet setting tool with a head piece for accommodating a rivet in particular, with a mechanism for gripping and/or pulling, in particular a rivet stem, and, connected to the mechanism for gripping and/or pulling a rivet stem in particular, a pulling device which additionally has an arrangement including at least one piezoelectric sensor for measuring the tensile stress of the pulling device.

The arrangement for measuring the tensile stress of the pulling device allows its measured values to be determined and analyzed. It has been found that a measurement of the tensile stress curve during a rivet setting cycle provides detailed

information on the rivet setting process, and it is possible in particular to detect faulty rivet setting operations using the tensile stress curve.

The piezoelectric sensor used for measuring the tensile stress is inexpensive, provides exact measured values, and can be accommodated in an extremely small space. Moreover, such a sensor provides a voltage signal. Thus, in contrast to conventionally used strain gauges, a voltage supply is not necessary.

The invention is suitable for all types of rivet processing and setting tools, thus for example also rivet setting tools, blind rivet nut setting tools, lockbolt setting tools, etc.

Additional parameters may be recorded for monitoring the setting process. For example, it can be advantageous to record the instantaneous position of the pulling device by means of a device for measuring the pulling device position, such as a displacement sensor, so that tensile stress/position pairs can be analyzed.

The tensile stress can be measured indirectly in a simple manner by means of a pressure sensor, which for example measures the counteracting force exerted by the pulling device on a part of the rivet setting tool.

Hydraulically driven pulling devices, with which rapid setting cycles can be executed with reproducible setting parameters, are especially advantageous for industrial applications. However, the invention also encompasses electric, electrohydraulic and hydropneumatic pulling devices. Among electric pulling devices, a cordless device with an integrated rechargeable battery is especially advantageous.

An appropriate device can be integrated into the setting tool for measuring and evaluating the [sic] from the device for measuring the tensile stress of the pulling device.

Furthermore, a counter that counts setting cycles can be accommodated within the setting tool. A counter that uses the measured tensile stress values to record the number of setting cycles executed can, for example, be used to monitor maintenance intervals. In addition, the counter can be used to check whether any rivets have been omitted, especially on large assemblies having large numbers of rivets.

The measurement and analysis device can also include an arrangement for recording the date and/or time. Date recording can be used, for example, to monitor guarantee periods and maintenance intervals. As an example, the device can be designed to begin recording the date after a certain number of rivet setting cycles, so that, for example, a certain number of test cycles can be executed before date recording starts. With an additional arrangement for recording the time, it is possible, for example, to trace when faulty rivets were set.

The measured tensile stress values and/or the counter readings can also be transmitted to an external device by a suitable device for transmitting measured tensile stress values. This unit can be a computer for data analysis and/or control, for example. The signal transmission here can advantageously be accomplished with a device for transmitting infrared, ultrasonic or radio signals.

Moreover, the data can also be transmitted through a mobile telephone network to a mobile radio terminal device. In this way, for example, the data can be transmitted directly to a maintenance department or to the manufacturer for remote diagnosis in the event of a malfunction in the device. The manufacturer can likewise determine in this way whether the required maintenance intervals have been observed.

In addition, the device for gripping a rivet stem preferably has clamping jaws which are operated by a chuck connected to a draw spindle. The tensile stress here is transmitted through a draw spindle.

The setting device can also be equipped with an arrangement for connecting to a local network for rapid distribution of data to multiple external analysis devices.

It is also within the scope of the invention to specify a corresponding method for monitoring setting operations, which method can in particular be executed using a setting device in accordance with the invention. The method makes provision for introducing a part to be set into an opening provided for it and then exerting a pulling force on the part to be set, preferably a rivet stem, by means of a pulling device, in order to set the part, wherein during the application of the pulling force there is obtained at least one measured value that is caused or influenced by the pulling force acting on the rivet stem. In this regard, the measured value can be obtained at a predetermined point in time or in the stroke of the pulling device and can thus provide information on any rivets that are not optimally set.

It is preferred for multiple measured values to be obtained at regular time intervals during the application of the pulling force. This makes it possible to obtain a curve of the applied pulling force over time and thus to gain detailed information about the rivet joints.

The use of measured values obtained with a piezoelectric pressure sensor is particularly advantageous. With the large pulling forces that arise, even an extremely small sensor provides adequately high voltages for precise and interference-resistant measurements.

Lastly, the invention concerns a head piece for a setting tool which comprises an arrangement including at least one piezoelectric sensor for measuring the pulling force exerted by the pulling device. The function of this head piece corresponds to the attainment of the object of the invention per claim 60, with the difference that here the arrangement required to measure the pulling force is completely integrated into the head piece with a piezoelectric sensor. Thus, it is possible to provide a head piece with the function according to the invention for an existing setting device. This has the advantage that it is not necessary to purchase a complete setting device. The head piece can be provided with appropriate connections for setting tools from different manufacturers. In this regard, the head piece according to the invention benefits from the fact that the piezo sensor does not require a voltage supply.

Lastly, the invention concerns a rivet. The setting tool in accordance with the invention according to the features of claim 1 is dependent on the uniformity of the setting operations in comparing measured values, for example the tensile stress at a particular point in the setting operation. Rivets that have different properties are a primary disadvantage in this context. If the properties differ widely, for example because of different materials or due to manufacturing tolerances, the device cannot be programmed optimally. To this must then be added the tolerance limit for a setting operation, which in turn is disadvantageous for an optimal setting result. The object of the invention was thus also to provide a rivet whose properties are essentially consistent.

This object is attained in a surprisingly simple manner through a method for monitoring a rivet in accordance with claim 97. In accordance therewith, provision is

made that a tensile stress is applied to the rivet, in particular with a setting tool according to claims 1 through 60, and the change in the length of the rivet is measured and compared to a nominal value. In order to avoid damaging the rivet, the measurement is made in the elastic region. Using a nominal value for the change in length, or a force-displacement curve, it is possible to test whether the rivet has the intended properties.

In a preferred further development of the invention, the tensile stress is applied to the rivet stem of a blind rivet.

In a further development of the invention, rivets that do not lie within a predetermined tolerance range are rejected. The rejection can be accomplished automatically by the monitoring device.

In a further development of the invention, rivets that lie within a predetermined tolerance range are permanently marked. In this way, the quality test performed on the rivet is made visible. Confusing them with untested rivets is precluded in this way.

The invention is explained below on the basis of preferred example embodiments and with reference to the attached drawings, where identical reference numbers refer to identical or similar components in the individual drawings.

Shown are:

Fig. 1 a schematic view of a first embodiment of the invention,

Fig. 2 graphs of the tensile stress as a function of time,

Fig. 3A – 3D various embodiments of external arrangements for measurement and analysis of measured tensile stress values,

Fig. 4 a schematic cross-sectional view of an embodiment of the invention,

Fig. 5 a schematic view of a head piece of a setting device with sensors, and

Fig. 6 graphs of the tensile stress of different set parts as a function of time.

In the description below, reference is made primarily to the rivet setting operation, which is to say the setting of a rivet. Nevertheless, the rivet setting described here encompasses the setting of blind rivets, rivet nuts and in particular also the setting of lockbolts, even when this is no longer explicitly mentioned. Insofar as the specific embodiment requires a different head piece, tip, chuck or seat, one skilled in this art can adjust appropriately for the current requirements.

Fig. 1 shows a schematic view of a first embodiment of the rivet setting device in accordance with the invention. The rivet setting device 1 comprises a head piece 2 with adjusting nut 22 for accommodating a rivet 20, a body 6 and a hand grip 16. A manually actuated triggering arrangement 18 triggers a pulling device in the interior of the rivet setting device, which is connected to a device for gripping the shank or rivet stem of the rivet 20, so that the stem is pulled into the rivet setting device. It is preferred here that the device for gripping the shank or rivet stem comprises a chuck with two or more clamping jaws. The pulling device is supported on the head piece 2 of the rivet setting device so that the tensile stress exerted on the rivet stem is converted into a pressure exerted between the head piece and pulling device. Located on the head piece 2 is a sensor unit 3, preferably with a piezoelectric sensor, which measures the pressure arising between the head piece 2 and the pulling device when the rivet stem is pulled. The sensor produces a voltage signal that is essentially proportional to the tensile stress. This voltage is either transmitted directly through a cable 8 to an external

device 12 for measurement and analysis of measured tensile stress values, or is first amplified by the sensor unit, and then the amplified signal is transmitted.

A separate electronic analysis unit 15, which for example includes an electronic counter with date and/or time functions, can also be accommodated in a part 14 attached to the hand grip.

As an alternative to transmission through cable connections, transmission to an external analysis unit can also take place through appropriate devices for transmission and reception of infrared, ultrasonic or radio signals. In particular, the rivet setting device can also be set up to transmit the signals through a mobile telephone network to a terminal device, which makes it possible to achieve great distances between the rivet setting device and the external analysis unit.

In this embodiment, the rivet setting device 1 also has a displacement sensor 4, which determines the instantaneous position of the pulling device by means of a device for measuring the position of the pulling device and sends a corresponding signal to the external device 12 through a cable connection 10. The displacement sensor can be an optoelectronic or inductive displacement sensor, for example.

Fig. 2 shows graphs of the tensile stress as a function of time in the course of rivet setting cycles. Graph 100 shows the typical curve of tensile stress under optimal conditions. has a minimum of tensile stress [sic]. Up to this minimum, the rivet head is compressed by the pulling force exerted by the pulling device of the rivet setting device. Thereafter, the pulling force continues to increase until the rivet stem breaks off and the tensile stress abruptly drops to zero.

Graphs 101, 102 and 103 show curves of tensile stress under non-optimal conditions. Graph 101 shows the curve of tensile stress with a hole diameter that is too large. In this case, the minimum between the two maxima is not as deep as in the optimal case, and is at a somewhat later point in time. In addition, in the case of a hole diameter that is too large, a higher tensile stress must be exerted up to the break-off of the stem and the break-off occurs at a somewhat later point in time.

Graph 102 shows the curve of tensile stress for a rivet that is not fully inserted in the hole, and graph 103 for a riveting operation without material, i.e. where the rivet has not been placed in a hole in a metal sheet. In both cases, the minimum of the tensile stress, and the time of stem break-off, are at a somewhat later time as compared to the curve under optimal conditions.

These graphs make it clear that the curve of the tensile stress over time can provide detailed information about the state of the rivet that has been set.

The following makes reference to Figs. 3A to 3D, which show embodiments of external devices for measuring and analyzing measured tensile stress values from the invention.

Fig. 3A schematically shows an analysis unit 24 that is connected by a cable connection 8 to the sensor unit 3 of the rivet setting device 1. In place of the cable connection 8, the sensor unit and the analysis unit can also be connected to one another by a transmitter/receiver unit for infrared, ultrasonic or radio signals, where the sensor is appropriately equipped with a transmitter and/or receiver.

The analysis unit 24 includes an LCD display 26 and operating elements 28. The LCD displays current results of measurements, such as the maximum tensile stress

reached for example. The measurement and analysis results are determined by suitable measurement electronics in the unit 24. The operating elements can be used to enter various functions, such as performance of a reference measurement, thresholds for warning messages, and resetting the current measured values.

Fig. 3B shows an extension of this system, wherein a printer 32 is connected to the analysis unit 24 by a cable connection 30. Current measurement results and additional data can be output by means of the printer 32. The printer can be operated by means of the operating elements 28, for example.

Fig. 3C shows an embodiment in which the measured values from the sensor unit 3 of the rivet setting device are transmitted by a cable connection 8 to a computer 34 as the analysis unit. To this end, the computer can preferably be a workstation equipped with a suitable plug-in card which accommodates analysis electronics for the transmitted measured values. For example, the measured stress values are digitized at regular intervals by an ADC component and can then be further processed by means of suitable software. The processed measured data and analysis results are then displayed on the screen 36 of the computer.

Fig. 3D shows another embodiment in which multiple rivet setting devices are connected to an analysis unit 38 by cable connections 81, 82, 83 and 84. The embodiment is shown in Fig. 4 for four rivet setting devices by way of example. However, this design can be expanded to any desired number of devices. The design can also be used equally well for a single rivet setting device. Each rivet setting device is connected by the cable connections to one of the blocks 381 to 384 of the analysis unit 38.

The analysis unit 38 in turn is connected by a connection 40 to a network node 42, from which the data can be distributed to multiple computers 341 to 344.

Fig. 4 shows a schematic cross-sectional view through an embodiment of the invention which can be used to explain the principle of the tensile stress measurement. Located in the body 6 is a hydraulic cylinder 50. In the cylinder 60 [sic] runs a hydraulic piston 52, to which is fastened a draw spindle 54, which transmits the force exerted by the piston to a chuck 56 attached thereto. When a force is exerted by the piston in the direction of the arrow, in that a suitable hydraulic fluid is forced into the cylinder section 51, clamping jaws 58 are initially pressed together by the retracting chuck 56 until a rivet stem located therebetween is gripped and clamped in place. The clamping jaws then pull the rivet stem further into the head piece 2 of the rivet setting tool until it is broken off by the rivet head approaching the adjusting nut 22. The piston can also be hydropneumatically driven, where the hydraulic fluid can be forced into the hydraulic cylinder 50 by means of an additional pneumatically driven piston, which can for example be located in the part 14 attached to the hand grip shown in Fig. 1.

As a result of the pulling force exerted by the chuck 56, a pressure is exerted on the head piece 2. The head piece 2 is attached to the body 6 in such a way that the pressure is not transmitted directly to the casing of the head piece 2, but instead is transmitted through a piezoelectric material part 31 located between the head piece and body. A piezo voltage resulting therefrom can then be transmitted by the electrical connections 60 and 62 to a suitable connecting plug 64. The pressure sensor can likewise be connected to a suitable electronic measurement and analysis unit that is integrated in the rivet setting tool itself.

Fig. 5 shows a schematic top view of a head piece for a setting tool according to the invention. Visible there is the adjusting nut 22 of the head piece 2. Three sensors 70 are attached around the adjusting nut 22. When the device is applied, all three sensors contact the part to be fastened only if the device is standing at right angles to the part to be fastened. In this way, it is possible to monitor whether the operator is making an error. If the device is not applied at right angles, an electronic unit ensures that the device is locked, and thus the setting operation cannot even be started.

Fig. 6 shows four graphs in which the tensile stress exerted during a setting operation is plotted over time, where the x-axis represents time and the y-axis represents force. Graph 90 shows the force-time curve during setting of a rivet nut. Here, the force initially rises sharply in the elastic region, transitions to the plastic region, and remains approximately constant until the end of the setting operation. Graphs 91, 92 and 93 show the force-time curves for various blind rivets. Here, the force also rises into the region of plastic deformation until the rivet stem breaks off and the force drops to zero. It can be seen that the force-time curves are very different for different rivets. Thus, it is necessary to program the device for specific setting operations. A variety of causes of faults can be identified on the basis of deviations from these curves alone. For example, if the force for a blind rivet rises in the elastic region later, then the blind rivet has only gripped the part to be set. If the hole is too big, the curve will rise more gradually in the plastic region. A large number of faults can be identified through comparison with stored causes of faults in this way. It is likewise conceivable to measure a force-displacement curve, or both a force-time curve and a force-displacement curve. Ideal values and typical deviations for specific causes of

faults can be precisely determined through analysis of completed setting operations. Analysis can be performed by setting various nominal fields 94, 95, 96. If the curve passes to the right of field 94, the blind rivet is gripping only the part to be fastened; if the transition from the elastic to the plastic region does not occur precisely in field 95, the hole is too big, or if the tensile stress does not drop to zero in field 96, the wrong rivet was used. Precise fault analysis is accomplished by means of many such fields that are traversed during the setting operation and make a fault cause identifiable. The sequential arrangement of individual fields also excludes specific causes of faults when the nominal values are met. For example, if field 94 is met, the possibility is ruled out that the mating piece was not gripped. Clear assignment of the various causes of faults is possible in this way.

Claims

1. Setting tool having a head piece, especially for accommodating a rivet, a gripping and/or pulling mechanism and, connected to the gripping and/or pulling mechanism, a pulling device, **characterized by:**
   - means for measuring the parameter values arising during the setting operation;
   - a mechanism for comparing the measured values with stored values;
   - a mechanism for determining a cause, in particular a cause of fault, for the deviation of measured values from stored values from a plurality of stored causes.

2. Setting tool from claim 1, **characterized in that** the parameter values comprise the tensile stress exerted by the pulling device and/or the position of the pulling device and/or the time since the start of the setting operation in question and/or the angle to the surface to which the setting device is being applied.

3. Setting tool from claim 1 or 2, **characterized by** the stored causes of fault:
   - device not applied at a right angle; and/or
   - incorrect rivet used; and/or
   - defective rivet; and/or
   - hole provided for the rivet is too large or too small; and/or
   - no rivet present in the setting tool; and/or
   - rivet does not grip both parts to be joined; and/or

- setting tool has a fault.

4. Setting tool from claim 1, 2 or 3, **characterized in that** the mechanism for measuring the tensile stress exerted by the pulling device includes a strain gauge.

5. Setting tool from claim 1, 2 or 3, **characterized in that** the mechanism for measuring the tensile stress exerted by the pulling device includes a piezoelectric sensor.

6. Setting tool from one of the preceding claims, **characterized in that** a capacitive sensor is provided for measuring the position of the pulling device.

7. Setting tool from one of the preceding claims, **characterized in that** the angle can be measured by means of at least three sensors arranged on the device head.

8. Setting tool from one of the preceding claims, **characterized in that** the setting tool includes means for data storage and/or further processing.

9. Setting tool from one of the preceding claims, **characterized in that** the means for data storage and further processing are resettable, especially during servicing of the device.

10. Setting tool from one of the preceding claims, **characterized in that** a chip is provided for comparison of measured and stored values and/or for data storage and further processing.

11. Setting tool from one of the preceding claims, **characterized in that** comparison of measured and stored values and/or data storage and further processing takes place in the device.

12. Setting tool from one of the preceding claims, **characterized in that** an independent energy source, in particular a rechargeable battery, is provided in the device for the means for comparison of measured and stored values and/or data storage and further processing.

13. Setting tool from one of the preceding claims, **characterized in that** the setting device includes a counter that counts rivet setting cycles and/or faults and/or causes of faults.

14. Setting tool from one of the preceding claims, **characterized in that** the setting device includes an arrangement for recording the date and/or time.

15. Setting tool from one of the preceding claims, **characterized by** an arrangement for transmitting measured values to an external unit.

16. Setting tool from claim 15 wherein the arrangement for transmitting measured values comprises an arrangement for transmitting infrared, ultrasonic or radio signals, in particular “Bluetooth”.

17. Setting tool from claim 15, [**characterized in**] **that** data transmission takes place by means of an optical waveguide.

18. Setting tool from claim 15, 16 or 17, wherein the external unit comprises a computing unit.

19. Setting tool from claim 15, 16, 17 or 18, wherein the external unit comprises a mobile radio terminal device.

20. Setting tool from one of claims 1 – 19, further **characterized by** an arrangement for turning off the rivet setting device and/or displaying the cause of the fault in response to a signal generated in the event of a faulty rivet setting operation.

21. Setting tool from claim 20, wherein the signal is generated by an external unit.

22. Setting tool from one of claims 1 – 21, **characterized by** a device for connecting to a local network.

23. Setting tool from one of claims 1 – 23 [sic], wherein the pulling device includes a draw spindle and the device for gripping a rivet stem includes clamping jaws for clamping a rivet stem.

24. Setting tool from one of the preceding claims, **characterized in that** the pulling device is operated electrically, in particular with a rechargeable battery, electrohydraulically, hydraulically, or hydropneumatically.

25. Setting tool from claim 24, **characterized in that** a line for supplying compressed air or electricity, and at least one additional line for transmitting the measured values can be connected to the setting device, and the additional line forms, together with the first line, one cable with one connector.

26. Setting tool from one of claims 1 – 24, **characterized in that** the device can be driven by means of an internal energy source, in particular a rechargeable battery.

27. Setting tool from one of the preceding claims, **characterized in that** the tool has an arrangement for performing a test cycle after switch-on.

28. Method for monitoring setting operations, in particular rivet setting operations, comprising the steps:

- insertion of a part to be set in a setting device, preferable a setting device according to the preceding claims;
- application of a pulling force by means of a pulling device to the part to be set;

characterized by the steps

- measurement of the parameter values that occur;
- comparison of the measured values with the stored values;
- determination of a cause, especially a cause of fault, for the deviation of measured values from stored values from a number of stored causes.

29. Method from claim 28, **characterized in that**, measured as parameter values are the tensile stress exerted by the pulling device and/or the position of the pulling device and/or the time since the start of the setting operation in question and/or the angle to the surface to which the setting device is being applied.

30. Method for monitoring setting operations from claim 28 or 29, further **characterized by** the determination of the stored causes of fault:

- device not applied at right angles; and/or
- incorrect rivet used; and/or
- defective rivet; and/or
- hole provided for the rivet is too large or too small; and/or
- no rivet in the device; and/or
- rivet does not grip both parts to be joined; and/or
- setting tool has a fault.

31. Method for monitoring setting operations from claim 28, 29 or 30, **characterized in that** the tensile stress exerted by the pulling device is measured by a strain gauge.

32. Method for monitoring setting operations from claim 28, 29 or 30, **characterized in that** the tensile stress exerted by the pulling device is measured by a piezoelectric sensor.

33. Method for monitoring setting operations from one of the preceding claims, **characterized in that** the position of the pulling device is measured by means of a capacitive sensor.

34. Method for monitoring setting operations from one of the preceding claims, **characterized in that** rivet setting cycles and/or faults and/or causes of faults are counted.

35. Method for monitoring setting operations from one of the preceding claims, **characterized in that** the date and/or time are measured.

36. Method for monitoring setting operations from one of the preceding claims, **characterized in that** the measured values and/or faults and/or causes of faults are forwarded to an external unit.

37. Method for monitoring setting operations from one of the preceding claims, **characterized in that**, in the event of a faulty rivet setting operation, the cause of the fault is displayed and/or the rivet setting device is turned off in response to a generated signal.

38. Head piece for a setting tool, in particular for a setting tool according to claims 1-27, **characterized by**:

- means for measuring the parameter values arising during the setting operation;
- a mechanism for comparing the measured values with stored values;
- a mechanism for determining a cause, in particular a cause of fault, for the deviation of measured values from stored values from a plurality of stored causes.

39. Head piece for a setting tool from claim 38, **characterized in that** the parameter values comprise the tensile stress exerted by the pulling device and/or the position of the pulling device and/or the time since the start of the setting operation in question and/or the angle to the surface to which the setting device is being applied.

40. Head piece for a setting tool from claim 38 or 39, **characterized by** the stored causes of faults:

- device not applied at right angles; and/or

- incorrect rivet used; and/or
- defective rivet; and/or
- hole provided for the rivet is too large or too small; and/or
- no rivet in the device; and/or
- rivet does not grip both parts to be joined; and/or
- setting tool has a fault.

41. Head piece for a setting tool from claim 38, 39 or 40, **characterized in that** a mechanism for measuring the tensile stress exerted by the pulling device is provided that comprises a strain gauge.

42. Head piece for a setting tool from claim 38, 39 or 40, **characterized in that** a mechanism for measuring the tensile stress exerted by the pulling device is provided that comprises a piezoelectric sensor.

43. Head piece for a setting tool from one of the preceding claims 38 – 42, **characterized in that** a capacitive sensor is provided for measuring the position of the pulling device.

44. Head piece for a setting tool from one of the preceding claims 38 – 43, **characterized in that** the angle can be measured by means of at least three sensors arranged on the front side.

45. Head piece for a setting tool from one of the preceding claims 38 – 44, **characterized in that** the setting tool includes means for data storage and/or further processing.

46. Head piece for a setting tool from one of the preceding claims 38 – 45, **characterized in that** the means for data storage and further processing are resettable, especially during servicing of the device.

47. Head piece for a setting tool from one of the preceding claims 38 – 46, **characterized in that** a chip is provided for comparison of measured and stored values and/or for data storage and further processing.

48. Head piece for a setting tool from one of the preceding claims 38 – 47, **characterized in that** comparison of measured and stored values and/or data storage and further processing take place in the head piece.

49. Head piece for a setting tool from one of the preceding claims 38 – 48, **characterized in that** an independent energy source, in particular a rechargeable battery, is provided in the head piece for the means for comparison of measured and stored values and/or data storage and further processing.

50. Head piece for a setting tool from one of the preceding claims 38 – 49, **characterized in that** the head piece includes a counter that counts rivet setting cycles and/or faults and/or causes of faults.

51. Head piece for a setting tool from one of the preceding claims 38 – 50, **characterized in that** the head piece includes an arrangement for recording the date and/or time.

52. Head piece for a setting tool from one of the preceding claims 38 – 51, **characterized by** an arrangement for transmitting measured values to an external unit.

53. Head piece for a setting tool from claim 52, wherein the arrangement for transmitting measured values comprises an arrangement for transmitting infrared, ultrasonic or radio signals, in particular "Bluetooth".

54. Head piece for a setting tool from claim 52, [**characterized in**] **that** data transmission takes place by means of an optical waveguide.

55. Head piece for a setting tool from one of claims 52 – 54, wherein the external unit comprises a computing unit.

56. Setting tool from one of claims 52 – 55, wherein the external unit comprises a mobile radio terminal device.

57. Head piece for a setting tool from one of claims 38 – 56, further **characterized by** an arrangement for turning off the rivet setting device and/or displaying the cause of the fault in response to a signal generated in the event of a faulty rivet setting operation.

58. Head piece for a setting tool from claim 57, wherein the signal is generated by an external unit.

59. Head piece for a setting tool from one of claims 38 – 58, **characterized by** a device for connecting to a local network.

60. Setting tool, more particularly rivet setting tool, comprising

- a head piece, in particular for accommodating a rivet
- a mechanism for gripping and/or pulling, in particular a rivet stem, and
- a pulling device connected to the mechanism for gripping and/or pulling a rivet stem in particular,

characterized by

- an arrangement, comprising at least one piezoelectric sensor, for measuring the tensile stress exerted by the pulling device.

61. Setting tool from claim 60, **characterized by** a mechanism for measuring the position of the pulling device.

62. Setting tool from claim 60 or 61, **characterized in that** the device for measuring the tensile stress exerted by the pulling device includes a pressure sensor.

63. Setting tool from claim 62, **characterized in that** the pressure sensor is a piezoelectric pressure sensor.

64. Setting tool from one of claims 60 – 63, **characterized in that** the pulling device is operated electrically, in particular with a rechargeable battery, electrohydraulically, hydraulically, or hydropneumatically.

65. Setting tool from one of claims 60 – 64, **characterized by** an arrangement for measuring and analyzing the measured tensile stress values.

66. Setting tool from claim 65, **characterized in that** the device for measurement and analysis of measured tensile stress values includes a counter that counts rivet setting cycles.

67. Setting tool from claim 65, **characterized in that** the device for measurement and analysis of measured tensile stress values includes a device for recording the date and/or time.

68. Setting tool from one of claims 60 – 67, **characterized by** an arrangement for transmitting measured tensile stress data to an external unit.

69. Setting tool from claim 68, wherein the arrangement for transmitting measured tensile stress data comprises an arrangement for transmitting infrared, ultrasonic or radio signals.

70. Setting tool from claim 68 or 69, wherein the external unit comprises a computing unit.

71. Setting tool from claim 68, 69 or 70, wherein the external unit comprises a mobile radio terminal device.

72. Setting tool from one of claims 60 – 71, further **characterized by** an arrangement for turning off the rivet setting device in response to a signal generated in the event of a faulty rivet setting operation.

73. Setting tool from claim 72, wherein the signal is generated by an external unit.

74. Setting tool from one of claims 60 – 73, **characterized by** a device for connecting to a local network.

75. Setting tool from one of claims 60 – 74, wherein the pulling device includes a draw spindle and the device for gripping a rivet stem includes clamping jaws for clamping a rivet stem.

76. Setting tool from one of claims 60 – 75, **characterized in that** it is a rivet setting tool.

77. Method for monitoring setting operations, in particular rivet setting operations, in particular undertaken with a setting device, preferably rivet setting device, in accordance with one of the preceding claims, comprising the steps:

- insertion of the part to be set, in particular a rivet, in an opening and
- application of a pulling force to the part to be set, in particular the rivet stem, by means of a pulling device,

characterized in that, during the application of the pulling force, at least one measured value is obtained that is caused or influenced by the pulling force acting on the part to be set, in particular on the rivet stem.

78. Method from claim 77, **characterized in that** multiple measured values are obtained at regular intervals during the application of the pulling force.

79. Method from claim 77 or 78, **characterized in that** the measured values are obtained by means of a piezoelectric sensor.

80. Method from one of claims 77 – 79, **characterized in that** the at least one measured value is compared with at least one nominal value.

81. Method from claim 80, wherein an error message is output by a display as a function of the deviation of the at least one measured value from a predetermined nominal value.

82. Head piece for a setting tool, in particular for a setting tool from claim 60-76, **characterized by** an arrangement, comprising at least one piezoelectric sensor, for measuring the tensile stress exerted by the pulling device.

83. Head piece for a setting tool from claim 82, **characterized by** a mechanism for measuring the position of the pulling device.

84. Head piece for a setting tool from claim 82 or 83, **characterized in that** the device for measuring the tensile stress exerted by the pulling device includes a pressure sensor.

85. Head piece for a setting tool from claim 84, **characterized in that** the pressure sensor is a piezoelectric pressure sensor.

86. Head piece for a setting tool from one of claims 82 – 85, **characterized by** an arrangement for measuring and analyzing measured tensile stress values.

87. Head piece for a setting tool from claim 86, **characterized in that** the device for measurement and analysis of measured tensile stress values includes a counter that counts rivet setting cycles.

88. Head piece for a setting tool from claim 86 – 87, **characterized in that** the device for measurement and analysis of measured tensile stress values includes a device for recording the date and/or time.

89. Head piece for a setting tool from one of claims 82 – 88, **characterized by** an arrangement for transmitting measured tensile stress data to an external unit.

90. Head piece for a setting tool from claim 89, wherein the arrangement for transmitting measured tensile stress data comprises an arrangement for transmitting infrared, ultrasonic or radio signals.

91. Head piece for a setting tool from claim 89 or 90, wherein the external unit comprises a computing unit.

92. Head piece for a setting tool from claim 89, 90 or 91, wherein the external unit comprises a mobile radio terminal device.

93. Head piece for a setting tool from one of claims 82 – 92, further **characterized by** an arrangement for turning off the rivet setting device in response to a signal generated in the event of a faulty rivet setting operation.

94. Head piece for a setting tool from claim 92 or 93, wherein the signal is generated by an external unit.

95. Head piece for a setting tool from one of claims 82 – 94, **characterized by** a device for connecting to a local network.

96. Head piece for a setting tool from one of claims 82 – 95, wherein the pulling device includes a draw spindle and the device for gripping a rivet stem includes clamping jaws for clamping a rivet stem.

97. Method for monitoring a rivet, in particular for a setting tool from claims 1 – 27, **characterized in that** a tensile stress is applied to the rivet, and the change in the length of the rivet is measured and compared to a nominal value.

98. Method from claim 97, **characterized in that** the rivet is a blind rivet and the tensile stress is applied to the rivet stem.

99. Method from claim 97 or 98, **characterized in that** rivets that do not lie within a predetermined tolerance range are rejected.

[text for Fig. 2:]

[x-axis:] Time

[y-axis:] Tensile stress